Review of the Fermilab Program

Report of the 2002 meeting of the URA Visiting Committee for Fermilab

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Executive Summary - Observations and Recommendations

The Fermilab program was reviewed by the 2002 Visiting Committee of the Universities Research Association (URA) on April 5 – 6, 2002. In the Appendix of this report we display the committee membership, meeting agenda, and charge from URA. The main text briefly describes the state of the Lab, its research programs, upgrade plans and future prospects. Here we summarize our findings and supplement those observations with comments, concerns and recommendations.

The Directorate has focused most of its attention in the past year on improving the luminosity performance of the Run II accelerator complex. To make Run II a success, significant luminosity increases must be attained and further machine and detector upgrades carried out. Goals for the run have been established, and they must be reached to attain the full physics discovery potential of the community's investment.

The Committee:

Supports the management's plans in this area, including plans to:

- Find a strong head for Beams Division who will assess and optimize the cultural and matrix management issues in the Division, with close support from the Associate Director for accelerators.
- Strengthen the control room support for machine studies and operational research for the long haul of Run II, primarily by calling on personnel resources already available inside Fermilab.
- Expand the exchange of physics and engineering personnel between Beams, Technical, and Particle Physics Divisions, with medium to long-term commitments.
- Continue to seek intellectual input and consultation from university and other accelerator laboratories, both national and international, where appropriate, by direct contact with upper management at those institutions.
- Provide close oversight and support of the CDF and DØ upgrades to meet the tight schedule constraints.

Fermilab continues to provide strong leadership for the LHC accelerator project and is host lab for the US CMS effort.

The Committee:

- Congratulates Fermilab on their outstanding performance on the LHC and on CMS.
- Approves of the plan to provide a common office space for CMS collaborators.

In the area of Lepton flavor physics, the NuMI/MINOS project will be an important element of the FNAL program during the second half of this decade, and has drawn considerable management attention this year. In addition, the MiniBooNE experiment is nearing completion.

The Committee:

- Congratulates the lab on the timely completion of construction of the MiniBooNE experiment.

- Congratulates the lab on completion of the difficult rebaselining process for the NuMI/ MINOS project.

- Recommends continued vigilance on cost, schedule, and ES&H compliance for the project.

The lab plays a significant role in particle astrophysics, including work on the Sloan Digital Sky Survey, the Cyrogenic Dark Matter Search, and the Pierre Auger Project. Each project is well underway and in good shape.

The Committee:

- Endorses the efforts planned for the PRIME mission, as the mission will nicely complement the ongoing SDSS work.

- Applauds the involvement of FNAL in particle astrophysics. The science is first-rate and the research substantially augments the intellectual strength of the laboratory.

The broad plan outlined above is supported by an active theoretical group and program of advanced accelerator R&D.

The Committee:

- Agrees that additional junior staff should be added to the theory group when budget allows.

- Endorses the Lab's choices on advanced accelerator R&D areas of emphasis.

1. General Overview

Fermilab Director, Michael Witherill, presented to the URA Visiting Committee an overview of the Lab's current status, preparations for upgrades and new initiatives, and planning for the future. Research goals for those programs were then elaborated on by Associate Director, Michael Shaevitz.

During the past few years, much of the Tevatron accelerator complex has been rebuilt and many new elements added for the Run II program. The CDF and DØ detectors are also, for the most part, new. The Run II physics program at the Tevatron is a broad one, encompassing both physics of the weak energy scale and CP violation and quark flavor physics. The collider Run II is the most important activity at Fermilab. The Run II program is the best opportunity we have in the world particle physics program to make new discoveries for some time.

Unfortunately, the collider performance is off to a disappointing start. Some things are going well, eg. the recycler has demonstrated design aperture and acceptable beam lifetime, and stability of operations are at normal levels. However, the delivered luminosity is still low, despite gradual recent progress. Detailed plans have been formulated to address the problems uncovered during startup, and steps are being taken to increase and focus the effort.

While Run II is the Lab's most important activity, and every effort must be made to deliver as much integrated luminosity as possible over the next 6+ years, the Lab's other major projects, LHC, CMS, MiniBooNE, and NUMI, must be kept on schedule.

US-LHC continues to be an important success story for the Lab. The project is 73% complete, and recent reviews have been very positive. Fermilab oversees the overall project and carries out work on the IR quadrupoles and integration. US-CMS is also a success story for the Lab. About 65% of the work is complete, and planning for transition to the research program is well along.

MiniBooNE will make a decisive check of the LSND anomaly. MiniBooNE will begin operating this summer. The NUMI project received special attention throughout 2001, with extensive restructuring of the project during the year.

In the area of Particle Astrophysics, the Sloan Digital Sky Survey is starting to come to fruition. Its detailed mapping of galaxies and other distant sources promises to revolutionize our view of the universe. Fermilab is also coordinating efforts for the Pierre Auger project which will study ultra high energy cosmic rays and the Cold Dark Matter Search which is being upgraded and moved to the Soudan mine.

In addition to its current experimental program, Fermilab supports very active theory groups in particle physics and astrophysics. The particle group is particularly strong in phenomenology and lattice gauge theories. It provides intellectual leadership as well as support for experiments and future planning. The astrophysics group provides strong leadership and an interface for the experimental activities. Both groups have been extremely successful in training young physicists.

In terms of future planning, the Lab is pursuing R&D for a next generation of rare kaon decays at the Main Injector as well as a dedicated detector for *B* studies, *B*TeV, at the collider. Funding for *B*TeV during the period of collider and detector upgrades for Run IIb and construction of NUMI/MINOS is a major issue facing the Lab and the community.

Long term planning for Fermilab's future requires R&D as well as physics studies that chart a realistic course. The Lab has been pursuing three areas: Very Large Hadron Collider (VLHC) R&D, Muon Collider – Storage Ring Studies and electron-positron linear collider (LC) studies.

The last of these is the most realistic possibility in the near term. The priority of the Lab is to make good progress on LC R&D during the next year in spite of budgetary limitations.

2. Tevatron Run II

The laboratory director laid out the luminosity goals for Run IIa, corresponding to operations supported by the collider configuration envisioned during the Main Injector construction. The Run IIa integrated luminosity goal is 2 fb^{-1}, over a 2 or 3 year period. Run IIa luminosity goals are:

- 5×10^{31} $cm^{-2}s^{-1}$ Main Injector Project Baseline
- 8×10^{31} $cm^{-2}s^{-1}$ Extrapolating from Run 1 luminosity, 60% above goal; 36 bunches
- 2×10^{32} $cm^{-2}s^{-1}$ Incorporating Recycler operations; 103 bunches

The Run IIb integrated luminosity goal is 15 fb^{-1}, accumulated over a 3 or 4 year period. This corresponds to a peak luminosity of about 4×10^{32} $cm^{-2}s^{-1}$, achieved by increasing the anti-proton intensity beyond that envisioned for Run IIa by a factor of 3. Mike Church and Dave McGinnis reported on the status of Run IIa, and the preparations for Run IIb. Church has been Deputy Head of the Beams Division since January 1, 2002, and is in charge of the program to increase Run IIa luminosity.

2.1 Run IIa

Tevatron collider performance in Run IIa is off to a somewhat disappointing start, with a peak achieved luminosity of 1.4×10^{31} $cm^{-2}s^{-1}$ with about 17 pb^{-1} delivered in the first 3 months of 2002. Nonetheless, some things are going well. For example, the Recycler has now demonstrated its design aperture, a beam lifetime of 70 hours, and the cooling of anti-protons in all planes. The Recycler will be integrated into routine operations after the summer 2002 shutdown, and is expected to allow the number of bunches to increase from 36 to 103. Mike Church identified 4 major issues that currently limit the luminosity performance:

1. Anti-proton transverse emittances in the Accumulator stack are ~2 times larger than expected.

2. The proton longitudinal emittance after coalescence in the Main Injector is too large, ~4 eV-s at 150 GeV.

3. The proton and anti-proton beam lifetimes in the Tevatron at 150 GeV are poor -- 1 or 1.5 hours.

4. Long range beam-beam collisions cause anti-protons to be lost at 150 GeV, and during the low beta squeeze.

The dynamical cause for the unexpected factor of 2 increase of the anti-proton emittances in the Accumulator is still being investigated. It is assumed to be associated with the Accumulator lattice upgrade that took place in preparation for Run II, in order to enhance anti-proton cooling performance. One hypothesis, that the new optics also enhance the Intra-Beam Scattering effect, is being aggressively pursued.

It is expected that the longitudinal emittance of the coalesced proton bunches will be significantly reduced when beam loading compensation is introduced to the 53 MHz RF cavities in the Main Injector, an upgrade which will happen in this year's summer shutdown.

The last two of these issues are rooted in the need to operate with helically separated orbits in most of the Tevatron circumference, in order to limit the number of head-on beam-beam collisions to just two -- at the CDF and DØ interaction points. If the helix amplitude is too small, then the cumulative effect of the many long range parasitic beam-beam interactions in the helix is too strong, and the anti-proton beam is damaged. If the helix amplitude is too large, then the tails of the proton (and anti-proton) beams begin to scrape at the edges of the dynamic aperture. The anomalously large transverse anti-proton emittances, and longitudinal proton emittances, both force the helix amplitude to be reduced. Even in the best of circumstances it is a time consuming and painstaking process to systematically explore the many parameters which are available in the tuning of the Tevatron, to optimize the beam dynamical performance of the helix.

An anti-proton beam-beam parameter of $\xi \approx 0.007$ has already been achieved in Run IIa, matching the world record value for hadron colliders first achieved in Run 1. With two head-on collisions, this generates a head-on anti-proton tune shift of approximately 0.014, plus a long range tune shift of about 0.005 from parasitic collisions in the arcs. These tune shift parameters are only rough indicators of the beam-beam resonance strengths, which are sensitive to the detailed geometry of the collisions -- especially the complex set of long range collisions. The beam-beam interaction will become even more challenging when the number of bunches is increased from 36 to 103. Not only will the long range tune shifts and resonances be driven harder, but also a new set of "near range" parasitic collisions will appear, near to each IP where the helix has not had chance to build up to its full amplitude. It is planned to introduce a collision crossing angle to further separate the beams at these locations.

The nominal plan for the evolution of luminosity takes no credit for the presence of the innovative and exciting electron lens, which is currently being commissioned in the Tevatron. Nonetheless, it is hoped that the electron lens will become a powerful new weapon capable of compensating for beam-beam tune shifts. When it operates in "linear" mode, the electron lens suppresses tune shift differences between anti-proton bunches at different locations in the bunch train. Ideally there would be two electron lenses. In "nonlinear" mode it is even hoped to be able to suppress the tune spread inside individual bunches. The Fermilab experience with electron lens operation will be closely watched by all hadron collider laboratories. Its success in operation would be a great achievement. Nonetheless, it is wise for Fermilab to take a conservative approach and to take no credit for electron lens operation in the planning for Run IIa and 2b.

It is likely that the underlying limitations to good luminosity performance will only be understood with carefully controlled and executed beam-physics experiments, coupled with careful simulation. As a result, there are two issues which are central to the diagnosis of the Tevatron luminosity difficulties. The first concerns beam diagnostics and instrumentation. Laboratory management should place adequate emphasis on the issue of beam instrumentation to

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ensure that the existing instrumentation is functioning properly, and that resources are available to deploy when other instrumentation needs arise. Secondly, the pool of beam-physicists presently involved in machine studies and operational research needs to be substantially increased. Capable beam physicists need to be identified from within the Beams Division, or elsewhere within the laboratory, to help carry out the necessary machine studies experiments and to help interpret the results. Finally, simulation efforts are beginning to, and will certainly continue to, play a central role in understanding the limitations to machine performance. The laboratory management is encouraged to make use of all available simulation resources, both within and outside the Beams Division. In particular, this may be one area where high-energy-physics experimenters, with adequate supervision, may play a key role.

Finally, the laboratory management is encouraged to foster in whatever ways possible, an approach within the laboratory which breaks down existing "sociological" barriers in order to encourage participation and contributions from all laboratory staff.

2.2 Run IIb

The Run IIb program calls for hardware improvements to be completed by FY05, and for "flat-out" running in FY06-FY08, during which luminosity is delivered at the rate of 3.85 fb^{-1} /year. The "luminosity schedule" relies on the fact that there are no long shutdowns planned between the present and FY08, apart from a single 4-6 month shutdown for the installation of new silicon detector components for the collider detectors.

Assuming that the present luminosity difficulties are overcome, the main limitation to Tevatron luminosity is thought to be the anti-proton intensity, so that is the thrust of the Run IIb upgrades. The Run IIb goal calls for a dramatic increase in the anti-proton production rate from the present 11×10^{10}/hr to 62×10^{10}/hr. This is accomplished with several improvements. First, the Recycler ring will be available to recycle anti-protons remaining at the end of a Tevatron store. Second, greater proton intensities on the production target are made by "slip-stacking" two Booster batches in the Main Injector. This will provide a factor of 1.8 increase in the proton intensity on the anti-proton target, and a subsequent increase in the anti-proton production rate. The increased proton bunch intensity in the Main Injector requires beam-loading compensation in the RF system.

Further improvements will be made in order to increase the anti-proton collection efficiency by a factor of 2. This is achieved with a new solid Lithium lens with 30% higher gradient than the present lens. In addition, the vacuum chamber apertures of the anti-proton collection transfer line and the Debuncher ring will be increased by removing a few known aperture restrictions.

With greater anti-proton yields, the cooling capabilities in the Anti-proton Accumulator and Recycler must be optimized. The Anti-proton Accumulator stacktail momentum stochastic cooling system will be modified to handle the increased flux. This means that the cooling burden will be placed on the Recycler, where electron cooling is planned in order to cool the large anti-proton stacks required for Run IIb.

The electron cooling program has been making good progress. The Pelletron-based cooling system has operated at 3.5 MV with 300 mA circulating current. This is a very impressive result, and one which bodes well for the future deployment of the system. The electron-cooling project goal is to achieve 500 mA circulating current at 4 MV.

The Run IIb team has assembled a detailed Run IIb Report which outlines the various components of the upgrade plan and the expected luminosity benefit. The committee is pleased to see this detailed upgrade plan in place. The Beams Division management is urged to identify and concentrate efforts on the high-payoff components of the plan. Finally, the committee concurs with the laboratory management that it is appropriate at this time to seek a Run IIb project manager.

2.3 DØ

The DØ collaboration is congratulated for notable progress on the detector since the last Visiting Committee meeting. Data processing has kept apace with data acquisition, and the many physics distributions shown from the ~27 pb^{-1} of data delivered by the Tevatron demonstrate that the collaboration is prepared and poised for the physics. DØ has also been establishing a data grid for both MC generation and offsite analysis, with five MC and 16 analysis sites already established in the US and Europe.

The one area of concern is the delay in the full implementation of the trigger, which is crucial for full utilization of the Tevatron luminosity. The collaboration is, of course, aware of this and hopes to complete implementation of the trigger this summer. Because of the shortfall in luminosity delivered by the Tevatron, this has not yet been a critical issue. Triggers based on calorimetry and the muon system are in place and working well. The level one CFT trigger awaited instrumentation of the VLPCs, but is now being commissioned. The level two trigger is being tuned, with the silicon-based component expected this summer. The level three linux farm, currently with 48 nodes, is operating well.

The collaboration is to be commended on their early recognition of the need to change the baseline DAQ implementation to an ethernet--based system, and for the implementation of a smooth, adiabatic upgrade that is expected to be in place this summer.

DØ appears to be on a course to take full advantage of the Tevatron luminosity as the accelerator is continually improved.

A set of upgrades to the Tevatron have been proposed to allow accumulation of 15 fb^{-1} of data (Run IIb) before commissioning of the LHC. The primary goal of the upgrade is the detection of a Standard Model (-like) Higgs Boson. While studies indicate that this goal is possible with the 15 fb^{-1} of data, the studies have assumed that the experiments have close to 100% leptonic trigger efficiency and 100% L1 efficiency for ZH to $\nu\nu$ b anti-b. The realistic performance will need careful examination to be sure Run II goals can be reached with the upgraded detector.

To meet the projected demands of Run IIb, the DØ Collaboration will need to replace its silicon detector and upgrade its trigger. These are major upgrades to the detector, with a total cost of approximately $30M and requirements of approximately 50-70 FTEs over the next two years. Furthermore, an aggressive timescale must be met for the upgrade to achieve its physics potential. This work must proceed even while commissioning proceeds with the current detector and physics analyses based on Run IIa develop. The DØ Collaboration should be commended for its well-organized management and resource--loaded planning, necessary ingredients for a project of this size operating under the given time and personnel constraints. DØ is further commended for pursuing the silicon R&D for the upgrade in cooperation with CDF, which significantly reduces the personnel that FNAL must devote to the upgrade.

Both the level 1 and level 2 triggers must upgrade to cope with both the increased rate and increased occupancies that will develop with the increased luminosity. A Conceptual Design Report for the level 1 trigger upgrade was completed in Oct., 2001, and reviews of detailed technical designs are slated for April, 2002. The upgrade needs at level one appear well-mapped out. The efficiency turn-on and the slow signal rise time are being addressed in the calorimetry trigger upgrade, while the thousand-fold increase in occupancy is being addressed in the track trigger. No changes are needed for the muon trigger, but it does require a functional track trigger. The upgraded trigger is expected to operate within the current level 1 bandwidth budget. The level 2 silicon trigger must be replaced to match the upgraded silicon geometry, and an upgrade of the level 2 processors is anticipated. As mentioned above, to meet the physics goals in the limited time available, the trigger upgrade must proceed in parallel with the commissioning work for the current trigger. The collaboration plans to meet some of the personnel requirements with people from new groups that are now joining.

2.4 CDF

The CDF collaboration should be congratulated on their remarkable progress in understanding the performance of the various detector systems since the last visiting committee meeting. The detector has been commissioned using the 12 pb^{-1} of Tevatron luminosity recorded by CDF during the last year. The performance of all the new detector systems, the Silicon tracker, the central tracker, the time of flight system and the impact parameter trigger was presented.

The Silicon tracker was shown to be working well. However one area of concern is that about 60% of the entire system (SVXII, ISL, and L00) is classified as working well. The experiment is still struggling to understand the issues pertaining to stability of the power supplies which render 10% of the SVXII and L00 and about half of the ISL unoperational at the moment. About 20% additional channels have some issues which need to be understood. The collaboration is taking steps to understand these problems and expects to resolve them soon. The signals from the Silicon detector were used to show the excellent performance of the new impact parameter trigger. This trigger is working extremely well and an impact parameter resolution of 48 microns has been achieved during online monitoring of a typical run. CDF also showed the performance of the time of flight detectors by reconstructing a phi resonance in 1.5 pb^{-1} of the data.

The CDF collaboration also demonstrated the preliminary physics performance in order to evaluate the detector functionality via the reconstruction of various resonances for example, J\psi, D^0, D^+, W and Z bosons, and also the jet E_T spectra. The detector has now moved out of the commissioning phase and is set to record physics quality data.

The visiting committee is looking forward to seeing some nice physics results next year with this detector.

The CDF collaboration also presented its proposed plans for further upgrade of the detectors to allow collection of 15 fb^{-1} data during the proposed high luminosity running period, Run IIb. This high luminosity running period together with detector upgrades will set the stage for low mass Higgs searches at the Tevatron before the LHC turns on at the end of this decade. CDF proposes to replace their Silicon Detector, the Central Preradiator and upgrade the Event Builder. The schedule and scope of this upgrade is quite aggressive to meet the challenges set by the time scale for RunIIb. The studies and simulations shown were of extremely preliminary nature and need to be completed in more detail. The expected improvements especially with the Central Preradiator upgrade needs to be justified with realistic simulations. Plans for schedule and preliminary cost estimate were also presented. No details of the resources required to mount the project were provided. This upgrade is a major undertaking for the collaboration and we urge them to carefully assess and identify the required resources, both physicist and technical, to carry out this project on an aggressive schedule.

2.5 Run II Computing

The status of DØ and CDF Run IIa computing systems and associated infrastructure for data access and reconstruction was presented. The RunII computing groups from CD, DØ and CDF should be commended for a successful implementation of computing systems which are capable of reliably logging and moving data on the scale of several TB's/day. Until now both the experiments have been reconstructing data in real time on the farms and there is a clear plan for adding more CPUs in the farm as well as analysis clusters in the future. The success of the computing infrastructure and the reconstruction farms is highlighted by the several physics signals shown by both experiments during the commissioning phase of the detectors. In addition, both experiments provide CPU and computing support to 150-300 users/day. No major changes to the infrastructure or software are planned for the near future. One of the major points of evolution on the data handling front has been the involvement in the Grid projects during the last year.

However, we are concerned about the lack of planning for RunIIb computing. The resources required for data reconstruction may well go beyond the lab and may involve distributing the tasks to major computing systems across the collaborating institutions. A clear plan of how the data handling and reconstruction will evolve for Run IIb and assessment of required resources needed for a reliable computing environment should be given high priority.

3. LHC/CMS

3.1 LHC

The Fermilab contributions to the construction of the LHC are going very well. The full scale prototype of the final focus quadrupole constructed at Fermilab has been successfully tested to a gradient of 228 Tesla/meter compared to the required operating gradient of 215 Tesla/meter. As a result, the second full scale prototype has been converted to the first production quadrupole and four more production quadrupoles are in process. The design work on the integration of the inner triplet system is nearly complete. Fermilab is responsible for the cryostat and the assembly of the entire inner triplet system using components supplied by KEK and CERN. The quadrupole project is about one month behind the original schedule but significantly ahead of the revised LHC schedule. Overall, the project is 75% complete in terms of committed funds.

The group at Fermilab plans to continue its participation with the rest of the US Hadron Accelerator Community in its collaboration with CERN with the goals of improving LHC performance, maintaining US capability in hadron accelerator design, supporting accelerator physics research, and continuing to advance international cooperation on large scientific facilities. Fermilab will act as host laboratory for this program. The scale of the program is targeted at the 10M$/yr level by FY2007 with a linear growth between now and then. An initial request of 0.3 M$ has been made for FY2002.

The Fermilab group is to be commended for an excellent job of managing and producing the components for the interaction regions of the LHC. Their planning for a robust research program with Fermilab acting as the host laboratory for the US LHC Accelerator Research Program will position them well to maintain a vital accelerator physics and design capability at Fermilab.

3.2 CMS

The Committee applauds Fermilab's role in the LHC and CMS. The Committee acknowledges and thanks for Fermilab for providing the Project Office and also for its plan to make the entire eleventh floor of the Wilson Hall available for the CMS activities. It will save the group travel time and money and help visitors to work and educate students in a coherent manner.

True to the US traditional role that has always spearheaded the energy frontier, the US members are expected to play a key role in CMS and ATLAS, the two major detectors of the next energy frontier machine. The US portion of the experiments is ~25% of the total construction effort. Fermilab is the host institution for the CMS collaboration and provides facilities for, as of now, some 387 members from 38 institutions. Components the group has made major contributions include:

1. Endcap Muon-Cathode Strip Chambers,
2. Hadron Calorimeter,
3. Endcap muon and calorimeter trigger
4. Portion of the Electromagnetic Calorimeter
5. Forward pixels
6. Endcap yoke, barrel cryostat and superconductor
7. Si Tracker.

In addition, Fermilab is selected as one of the five Tier I computing centers for the entire CMS/US group.

The Project Management is commended for organizing the group in such a way that the role of university groups is just as significant as that of major laboratories and that several members of the group hold key management positions within the whole CMS collaboration.

At this point, both the US and Fermilab construction activities continue to be on schedule and on budget. No technical issues involving hardware production appear to exist on the horizon. The

Project Management has even managed to make a 50% contingency reserve of the cost to complete and has decided to utilize part of it for expanding the scope of the Si Tracker. The Committee heartily endorses this decision since it is likely the key element for discovery of new particles beyond the standard model. The Project Management still keeps a reserve of ~15% contingency in hand which could be utilized for the maximum benefit of the experiment should such needs occur.

Overall, the Committee is pleased with the progress to date.

4. Lepton Flavor Physics

4.1 MiniBooNE

The MiniBooNE experiment is designed to confirm or refute the LSND experiment, which reported anti-$\nu_\mu \rightarrow$ anti-ν_e oscillations with Delta $m^2 \sim 10^{-(0-1)}$ eV^2. MiniBooNE will have ten times the statistics as LSND, as well as enhanced techniques for reducing systematic errors.

The experiment will detect neutrinos produced by the 8 GeV Proton Booster. It will search for ν_μ or anti-ν_μ oscillations using a mineral oil Cherenkov detector located on the Fermilab site. The detector will contain approximately 250k gallons of oil and about 1500 PMT's. It is presently about 80% full.

The detector and beam line are currently being commissioned, with high intensity neutrino beam due on June 15. The collaboration expects to run for about two years.

The Committee is pleased by the progress of MiniBooNE, and eagerly awaits its results!

4.2 NUMI/MINOS

The NuMI/MINOS project will be an important element of the Fermilab program during the second half of this decade. It will be a world-class facility for the investigation of neutrino properties. NuMI/MINOS will obtain firm evidence for neutrino oscillations by determining the oscillation parameters Delta m^2 and $\sin^2(2\,\theta)$ in the atmospheric oscillation region. It will also seek to determine the relevant oscillation modes.

The project has two major components: NuMI, a neutrino beam extracted from the Main Injector at Fermilab, and MINOS, a 5400-ton detector, located 730 km away in the Soudan mine, north of Duluth, Minnesota. A 980-ton near detector, located on the Fermilab site, will be used to control systematic errors.

The status of the project was presented by Greg Bock, NuMI Project Manager. He described a year of great activity:

- The project management was significantly strengthened;
- A new baseline was developed and approved;

- A safety corrective action plan was developed and implemented;
- The ES&H compliance of contractors and subcontractors was addressed and improved.

The new management plans have been the subject of numerous internal and external reviews.

The project rebaselining has increased the TPC by $33M, or 24%, all on the NUMI side of the project. It also added two years to the completion date, so CD4 is now scheduled for September 2005. The rebaselining was approved by DOE in December 2001. The project has been operating on the new plan since July 2001. Since then $22.5M of work has been done, and the project remains on cost and schedule.

During the past year there has been much progress on designing and engineering the NuMI technical components. The process is now more than 80% complete, as compared with 30% one year ago. As a result of this process, significant improvements were made to the primary beam optics.

As of April 2002, the excavation is 97% complete. The NuMI tunnels and halls are more than 71% complete, and are past their most critical phase. Nevertheless, the NuMI civil construction and the installation of the NuMI technical components are still the critical path for the project.

The schedule and costs are areas of concern. The schedule continues to be tight; beneficial occupancy is slated for November. Significant costs are anticipated associated with the schedule delays and with the resolution of claims and disputes with the contractor. Both issues are being closely monitored.

The MINOS detectors are on track for completion on budget and on schedule. The collaboration has installed over 158 planes of the far detector, and is closing in on completion of the first supermodule. Cosmic ray muons have been detected and displayed. Construction of the near detector is also well underway.

The Committee applauds Fermilab for the steps it has taken during the past year. As a result of these efforts, the project management is stronger, and the project itself is on track for successful completion. The Committee recommends continued vigilance on environmental and safety compliance. It is pleased by the improvements to the beam optics, and encourages the collaboration to beat the baseline.

5. BTEV

The BTEV collaboration has finished a major descoping plan, which involves instrumenting only one arm of the detector, plus obtaining magnets for the IR from either DØ or CDF. This results in a significant reduction in the project cost. We congratulate the collaboration on completing this painful, but crucial, exercise.

As part of the descoping, the analysis will be handled with distributed computing. We have some concerns about the viability of this plan, and encourage the collaboration to make a detailed resource loaded study.

Because of increased understanding of the detector capabilities, the physics reach of the detector with a single arm is now thought to be roughly equivalent to the initial proposal. We reaffirm our support for the physics goals of this experiment.

6. Particle Astrophysics

6.1 Experimental Astrophysics - SDSS

Results from the experimental astrophysics group at FNAL are among the most significant produced by the laboratory in recent years. The centerpiece of the program is the Sloan Digital Sky Survey (SDSS) which started its five year survey in 2000. The survey will cover approximately 8,000 square degrees (one-quarter of the total sky). Some 100 million galaxies will be imaged and spectra will be obtained on more than 1 million of these. SDSS will provide the first comprehensive catalog of the nearby ($Z < 1$) universe. The catalog will provide invaluable information about the three dimensional structure of the universe which can be used to probe key cosmological issues, such as the properties of dark matter and the nature of the fluctuations that led to structure formation in the early universe. The catalog will also be of great use for many other astronomical studies, such as in the discovery of very distant quasars.

SDSS is a collaboration of roughly ten U.S. institutions - among these, FNAL has played a key role. The FNAL group manages and directs the survey, and is responsible for acquiring and processing all the data. The FNAL heritage of handling the very large data sets of high-energy physics experiments has been important in dealing with the 40 TB of data from SDSS. FNAL scientists also play key roles in a number of the science investigations. The effort has benefited from the close connection between the theoretical and experimental astrophysics groups. Important early results include the discovery of stellar clumps in the Milky Way and quantifying the local structure in terms of the power spectrum. The initial SDSS spectrum supports a value for the matter density divided by the critical density of approximately one-quarter, which is consistent with the current paradigm. The spectrum can also be used to make a sensitive probe of the neutrino mass at the few eV scale.

The future of the experimental astrophysics group at FNAL looks bright. The Sloan Survey will be carried out through 2005, and scientific analysis will continue well after that. The group is starting to consider efforts beyond Sloan and has proposed a Small Explorer mission called PRIME. If approved, this mission would image some 4,000 square degrees of the sky in three infrared bands. PRIME would explore further out in redshift than SDSS, detecting quasars out to $Z=15$, and studying weak lensing and the evolution of large scale structure.

6.2 Pierre Auger Project

The Pierre Auger Project consists of two observatories, one each in the Southern and Northern Hemispheres. The Southern Hemisphere site is approved and under construction in Mendoza province in Argentina. A proposal for the construction of the Northern Hemisphere observatory will be submitted in the near future. Auger seeks to understand the mystery of the highest energy cosmic rays, especially those with energies greater than 10^{20} eV since particles at these energies are very difficult to produce via conventional astrophysical mechanisms and are not expected to travel far (< 100 Mpc) through interstellar space. In the last year, the importance of understanding the nature of high-energy cosmic rays has been underscored by a disagreement on the flux levels reported by the two major operating experiments (AGASA and HiRes). These two experiments use different detection techniques (air shower and fluorescence). Auger will combine both techniques and is thus expected to address both the main statistical and systematic errors associated with measuring the energies of this minute flux of particles.

Progress on the Southern observatory has been steady during the last year – a number of important milestones have been reached. The engineering arrays of forty surface detectors and two fluorescence detectors were installed and are now operational. Large air shower events are being routinely detected. The campus, consisting of a main building for data acquisition, offices, visitors, and a detector assembly building, is now fully functional. During the next 2-3 years, the full observatory (1,600 surface detectors, 33 fluorescence detectors) will be constructed and installed. The collaboration is now ramping up efforts to switch into production mode in order to complete the construction in a timely fashion.

The Auger Project is well on track and its prospects for important science results look excellent. The FNAL group has played a central role in the international Collaboration and among the U.S. groups participating in Auger. A major success story has been the project management, carried out well by the FNAL group. The group is also involved in design and construction tasks associated with the surface detectors. If anything, it would be desirable for the FNAL group to be larger in personnel so as to have an even greater impact within the collaboration. Nevertheless, the Auger effort is a valuable one for FNAL that adds to the scientific breadth of the laboratory.

6.3 Cryogenic Dark Matter Search (CDMS-II)

CDMS-II will be a state-of-the-art cryogenic detector designed to search for non-baryonic dark matter, such as weakly interacting massive particles (WIMPs). We know from a number of observations (especially from galactic dynamics and from CMBR anisotropy studies) that dark matter is certainly present in our galaxy and in the universe as a whole. Cold dark material, perhaps of the WIMP variety, is the leading candidate for dark matter. A detection of WIMPs would also signal the discovery of supersymmetry, whose existence is of key importance for particle physics.

CDMS-II can detect WIMPs (and separate them from background) by measuring their phonon and ionization signals in a low temperature semiconductor, such as germanium or silicon. The final experiment will consist roughly forty detectors, arranged into towers and comprising a target mass of more than 7 kg. CDMS-II will be located in the Soudan mine in northern Minnesota. The collaboration has built and operated a smaller detector (CDMS-I) in a relatively shallow facility on the Stanford University campus. The initial detector has been important in developing and refining the design and has placed limits on the WIMP cross-section that are currently the world's best.

such as b physics, where there is currently little activity. We support the addition of these scientists.

8. Advanced Accelerator R&D

Fermilab's program in advanced accelerator R&D has been funded at the 8 to 8.8 M$ level for the last three fiscal years. It is clear that this critical component for the future of Fermilab must grow to at least twice this level for Fermilab to be a credible player for the next large accelerator project. The main elements of their current program are room temperature linear collider R&D, superconducting RF R&D, superconducting magnet R&D on both high field and low field technologies, muon R&D focussed on developing an neutrino factory, and the design of a proton driver. Regrettably, due to severe budget constraints, they have ramped down their muon R&D effort to the level of 0.5 M$ this year and plan to keep it at that level through FY04. This will enable Fermilab to at least maintain some presence in this important area. They plan to ramp up the room temperature linear collider R&D component to 8 M$ per year by FY04 so that they can effectively participate in the understanding the challenges of this technology. In parallel, their effort in superconducting RF R&D will be ramped up to 7 M$ per year by FY04. It is very encouraging to see a very significant growth in this key area since Fermilab can play a critical role in developing a consensus on the choice of technology for a future linear collider. Developing expertise in both room temperature RF and superconducting RF technologies for a second generation linear collider positions Fermilab as a credible host and or construction partner for this key future facility.

Advancing knowledge in fundamental accelerator R & D and partnering with universities in the training of new students is one of the important goals of their program. The program in the Fermilab/NICADD Photoinjector Laboratory has an excellent track record in this area. The Committee was presented with list of very interesting future PhD topics that promises to increase the level of participation of the universities in training the next generation of accelerator scientists. Fermilab is to be commended for supporting this important activity.

R & D in superconducting magnet technology is an area that Fermilab has always held a leadership position. Hard choices were made this year resulting in a decision to not to continue work on the very successful low field magnet technology. The high field technology will continue at its current level of effort with a focus on LHC upgrade contributions. These activities will preserve the necessary expertise in the US to design and construct a future very large hadron collider.

Finally, the construction of a second-generation linear collider in this country is by no means a sure thing and the design and construction of a VLHC is even less certain. As a result a > 1 MW proton driver in the energy range of 14 GeV to provide neutrino super beams is under design. With the current excitement in neutrino physics and the recent SNO results pointing towards the large mixing angle solution such a beam could provide Fermilab with a bright future independent of the outcome the linear collider push. Again, they are to be commended in maintaining a broad program in R & D in the event that the first priority fails.

Overall, the Fermilab program in advanced accelerator R & D is well focused with clear goals and is providing excellent results.

The FNAL group has an important role within CDMS-II, including responsibility for the project management, the cryogenic system, the infrastructure at the Soudan mine, and various components of the detector (including electronics and DAQ). Historically, the group has been somewhat undermanned in terms of management and engineering staff - this has led to some schedule slippage. In addition, there have been difficulties related to the commissioning of the dilution refrigerator and to the construction of the experimental enclosures at the mine. These difficulties appear now to be largely overcome, and the overall progress on the construction of CDMS-II appears to be in good shape. The fabrication and characterization of the detectors is going well - testing results indicate that the experiment will achieve the required level of background rejection. Thus, one has confidence that, when complete and operational, CDMS-II will be able to reach the proposed sensitivity level (and start to seriously test supersymmetric models).

6.4 Theoretical Astrophysics

The group consists of 5 scientists, 5 postdocs, 1 Schramm fellow, visitors and graduate students. The group is widely recognized as being leaders in a number of important areas of astrophysics, including CMBR, large-scale structure, baryogenesis, dark matter/energy, and the ultrahigh energy cosmic rays. Close relations with the University of Chicago, especially joint appointments and access to students, have been important in maintaining a strong program. The group has been successful at maintaining independent funding from NASA (contributing approximately one-third of the support), at recruiting excellent postdocs, and at placing postdocs into good positions. Collaboration with the experimental astrophysics group has been mutually beneficial, and a number of theorists are closely involved with the SDSS and PRIME efforts. The FNAL theoretical astrophysics group is truly excellent and one can say with confidence that it will continue do forefront research.

7. Theory

Fermilab has a well-respected and active theory group, which carries out a vigorous frontier research program. The group is strong in phenomenology, perturbative QCD, lattice gauge theory, and supersymmetry. The lattice gauge theory group is involved with plans to develop a national user computing facility for lattice gauge theory under the DOE SciDAC initiative. This plan will allow the group to continue forefront lattice calculations.

The group has been extremely successful in training postdocs who continue in the field and in integrating itself with the lab's experimental programs. Theorists have organized and coordinated workshops and seminars focused on the Tevatron run II physics program. These interactions are important for the vitality of the lab.

The frontier fellows program brings senior scientists to Fermilab for an extended period of time and significantly enhances the group's research activities, as does the active summer visitor program.

The primary concern of the group is the hiring and retention of 4-5 additional junior staff members. The addition of these associate scientists could be used to strengthen the group in areas such as b physics, where there is currently little activity. We support the addition of these scientists.

8. Advanced Accelerator R&D

Fermilab's program in advanced accelerator R&D has been funded at the 8 to 8.8 M$ level for the last three fiscal years. It is clear that this critical component for the future of Fermilab must grow to at least twice this level for Fermilab to be a credible player for the next large accelerator project. The main elements of their current program are room temperature linear collider R&D, superconducting RF R&D, superconducting magnet R&D on both high field and low field technologies, muon R&D focussed on developing an neutrino factory, and the design of a proton driver. Regrettably, due to severe budget constraints, they have ramped down their muon R&D effort to the level of 0.5 M$ this year and plan to keep it at that level through FY04. This will enable Fermilab to at least maintain some presence in this important area. They plan to ramp up the room temperature linear collider R&D component to 8 M$ per year by FY04 so that they can effectively participate in the understanding the challenges of this technology. In parallel, their effort in superconducting RF R&D will be ramped up to 7 M$ per year by FY04. It is very encouraging to see a very significant growth in this key area since Fermilab can play a critical role in developing a consensus on the choice of technology for a future linear collider. Developing expertise in both room temperature RF and superconducting RF technologies for a second generation linear collider positions Fermilab as a credible host and or construction partner for this key future facility.

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Overall, the Fermilab program in advanced accelerator R & D is well focused with clear goals and is providing excellent results.

9. Program Planning and Management

A number of important successes in the Lab program within the past year were evident to the committee:

- vast improvement in the recycler performance
- completion of RunIIa construction
- re-baseline of NUMI/MINOS, completion of the NUMI tunnel
- LHC progress and oversight; planning for co-locating CMS efforts on 11th floor
- timely preparation of MiniBooNE
- correct choices on planning the accelerator R&D program within the tight budget constraints

The Lab's staffing plans make sense given the highly constrained budget – the Lab is open to hiring in the highly critical area of accelerator physics for Run II, with other hiring suppressed. The Lab is congratulated in the replacement of M. Shaevitz by H. Montgomery as Associate Director.

During their opening talks, Director Witherill and Associate Director Shaevitz laid out Fermilab's current and future plans. The Lab's program is a multi-pronged approach to the scientific goals recently laid out by the HEPAP Subpanel long-range planning document. The Lab plan includes work in electroweak symmetry breaking (currently: CDF/DØ; future: LHC/CMS, LC), lepton flavor physics (MiniBooNE, NUMI/MINOS), quark flavor physics (currently: CDF/ DØ; future: BTEV, CKM), cosmology and particle physics (SDSS, CDMS), and high-energy particle-astrophysics (Auger). This program is supported by ongoing efforts in Theory and accelerator R&D. This broad program seems appropriate for the flagship laboratory of the US HEP program and in all cases elements of the program require unique facilities, resources, personnel or capabilities available to the community only at the Lab. A case was made that this broad program can be supported within the budget guidance given by DOE, but with certain elements, particularly LC R&D, seriously underfunded relative to the goals desired by the Lab and the community. The quality of the program was judged by the committee to be very high.

However, the situation on the Run II luminosity presents a grave threat to future planning efforts. In the view of the committee, Lab management is fully engaged in the Run II problem, and well aware that not enough progress has been made. The management realizes that resources, attitudes, operations and expectations have to be adjusted for the long haul that will realistically be needed to meet Run II luminosity goals. Management is aware that the entire program depends on the success of this effort, as the level of effort dominates everything at the Lab, and the program is both high-impact and high visibility outside the Lab.

The committee made a number of suggestions to management regarding the Run II situation. These included:

- Establish a serious integration of Beams Division and their activities first with the rest of the Lab and later with the broader community.

- Continue to expand and delegate high level management involvement in the Run II issues. Strengthen the communication between the top management and the rank and file within the lab.

- Increase manpower available for beam operations from elsewhere in the Lab.

- Plan for a more formal process on Run IIb detector preparations as the committee had concerns about the adequacy of manpower for the upgrades, and the need to execute the upgrades to minimize turn off/turn on time to maximize integrated luminosity.

The committee endorses a number of steps being taken by management to help ease the situation, including:

- Appointment of a strong head for the Beams Division

- Increased personnel exchanges between Beams and the other Lab Divisions

- Consultation with other laboratories and solicitation of help from them

- Appointment of a Run IIb project manager

10. Fermilab Users

Christopher White reported on the activities of the User's Executive Committee (UEC). He began by reminding us of the UEC membership, and then outlined the significant activities in the past year for each of the UEC sub-committees. The Education and Outreach committee is carrying on an extensive program of public relations and awareness activities that impressed the Committee by its breadth. The Younger Physicist/Inreach committee is planning a career night for the end of May. The Quality of Life committee has surveyed users on issues of concern and is taking steps to resolve the issues. The Users' Meeting committee is well along in preparations for the June 10-11 Users' Meeting. The Washington Visit committee scheduled the joint Fermilab/SLAC visit for the end of April, and preparations were well underway at the time of our review.

The overall tone of the UEC report was very positive. The users appear to be very happy to analyze data!

URA Visiting Committee Meeting
5-6 April 2002
Comitium

Friday, April 5

8:00	Executive Session	
9:00	Fermilab Overview (45 min)	M. Witherell
9:55	Overview of the Research Program (30 min)	M. Shaevitz
10:30	Break	
10:50	The Tevatron collider in Run IIa (25 min)	M. Church
11:20	Run IIb Luminosity Upgrade (25 min)	D. McGinnis
11:50	Discussion	
12:00	Lunch	
1:00	DØ Status and Prospects (25 min)	J. Womersley
1:30	CDF Status and Prospects (25 min)	N. Lockyer
2:00	Run II Computing (25 min)	W. Merritt
2:30	DØ Upgrade Project (25 min)	J. Kotcher
3:00	Break	
3:20	CDF Upgrade Project (25 min)	P. Lukens
3:50	US-CMS (20 min)	D. Green
4:15	The US-CMS Software and computing project (15 min)	L. Bauerdick
4:35	US-LHC (20 min)	J. Strait
5:00	Executive Session	
6:30	adjourn for 7:00 Dinner	

Saturday, April 6

8:15	Accelerator R&D (50 min)	S. Holmes
9:15	Status of NuMI and MINOS (30 min)	G. Bock
9:50	Status of MiniBooNE (20 min)	A. Green
10:15	Break	
10:35	Recent Physics Results (25 min)	D. Harris
11:05	BTeV and CKM Plans (25 min)	J. Butler
11:35	Theoretical Particle Physics (20 min)	K. Ellis
12:00	Lunch	
1:00	CDMS and Auger (20 min)	R. Dixon
1:25	Theoretical Astro and SDSS (25 min)	J. Frieman
1:55	Users' Executive Committee Report (20 min)	C. White
2:20	Executive Session	
3:15	Discussion with Laboratory Management	
4:00	Adjourn	

Charge to the Visiting Committee for Fermilab

Although Fermilab is a single mission laboratory, its present scientific program is quite broad. It includes both collider, fixed target and neutrino oscillation experiments and the necessary accelerator operations and R&D for improving the existing accelerator complex. In addition, Fermilab has been asked by DOE to play a leading role in U.S. participation in the LHC, both on the accelerator side and in the CMS detector. The Laboratory also has an advanced accelerator R&D program for future accelerators, a program in experimental astrophysics, and theoretical programs both in particle physics and astrophysics. The URA Visiting Committee for Fermilab is charged with reviewing this scientific program and commenting on its quality, soundness, overall balance, and future prospects. The Committee is also encouraged to comment on the Laboratory Director's plans and priorities for Fermilab.

In its response to this charge, the URA Visiting Committee should try to address the following points:

i) Is the Fermilab program competitive at the world level, both in its broad scope and in the quality of its individual components? Are there any individual components which fall short of this standard?

ii) Is the balance in the laboratory between current programs an research and planning for future programs appropriate? Are adequate resources being applied to high priority activities?

iii) Are there areas of scientific endeavor where Fermilab could have a significant impact, which the laboratory should pursue more vigorously? Are there programs in the laboratory whose efforts require future review in order to determine whether they should continue?

iv) Have recent permanent staff appointments at Fermilab helped further the mission of the laboratory? Are there areas that are missing key people and which could be strengthened?

v) Does the laboratory management provide the scientific leadership needed for Fermilab?

vi) Does Fermilab provide the administrative, technical and scientific support needed by its users?

vii) Is the programmatic support for Fermilab's scientific mission adequate and are the laboratory resources used effectively? Are there efforts which should be commended and/or are there opportunities for improvement in specific areas?

viii) Are there any particular issues requiring special attention by URA?

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